Discrete Element Modeling of Fluid Injection Induced Seismicity and Fault Zone Slip

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Occurrence of relative larger magnitude seismic events induced by fluid injection in Enhanced Geothermal System (EGS) development, e.g. the Mw=3.2 event in 2006 in Basel EGS, has initiated an on-going debate on the potential risk in EGS development by fluid injection. In order to better understand the physics behind and to enable prediction of occurrence of larger magnitude events by fluid injection, various modeling tools have been developed. As one of many modeling methods, this numerical modeling study presents 2D discrete particle joints model by Particle Flow Code 2D (Itasca).

The objective of the study is to investigate evolution of seismicity and slip of fault zone induced by a nearby fluid injection. Injection of fluid into a geothermal reservoir with granitic rock mass properties and with an inclined through-going fault zone is tested. The physics of the fault zone behavior is modeled explicitly by combination of fault core fractures and damage zone. The reservoir model is in 2D and generic but its parameters are adapted to the setting of the geothermal reservoir rock mass in Soultz-sous-Forêts (France) and Basel (Switzerland).

We investigate numerically how fluid injection at different locations under different stress regimes affect the characteristics of the induced seismicity in terms of (i) shape of the evolution cloud, (ii) frequency-magnitude distribution, (iii) slip potential of the fault zone, (iv) spatial and temporal changes in the Gutenberg-Richter *b* value in relation to occurrence of larger magnitude seismic events.

Preliminary modeling results show that fluid injection at 200 m distance from the fault zone centre induces seismicity within the fault damage zone and slip of the fault fracture by small amount of fluid pressure perturbation (0.01<Pf<0.1 MPa). The modeling result shows that after the well shut-in the pressurized fluid migrates into the fault damage zone and reduces the frictional strength of the core fractures. Movement of the fault zone, therefore, is triggered which led to a seismic events of which the magnitude is larger than those induced by the fluid injection. Magnitude-frequency distributions of the seismicity catalogue shows progressive transition from a fracture dominated characteristics (lower magnitude events, high b-value) to a fault related characteristics (larger magnitude events by fault slip, low b-value) as the pressurized fluid migrates into the fault zone and causes slip of the fault fractures by reducing their frictional strength (Fig.1).

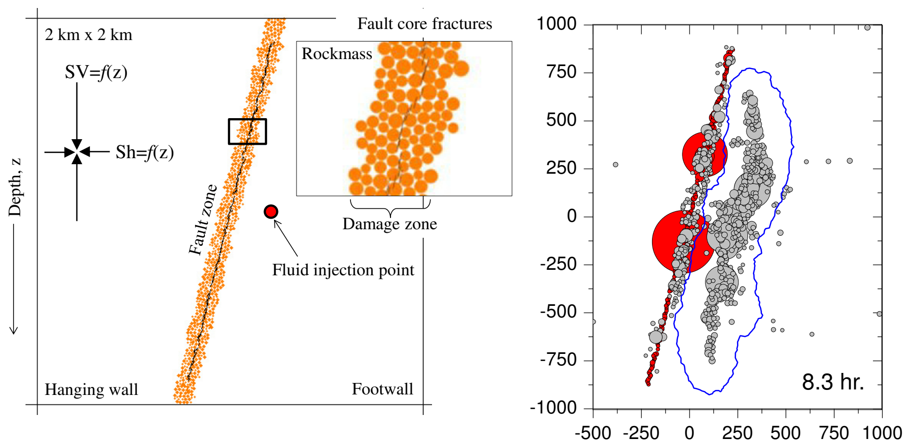

Fig.1. (Left) Geothermal reservoir model in 2 km x 2 km size with though-going fault zone (damage zone + fault core fractures) and subjected to normal faulting stress regime (SV>Sh) with both stress components varying with depth. (Right) Induced seismic events by fluid injection (within the 0.01 MPa fluid pressure contour, blue) and seismic events in the fault damage zone (gray) and the fault core fractures (red) triggered by the fluid injection, beyond the 0.01 MPa fluid pressure contour (blue).